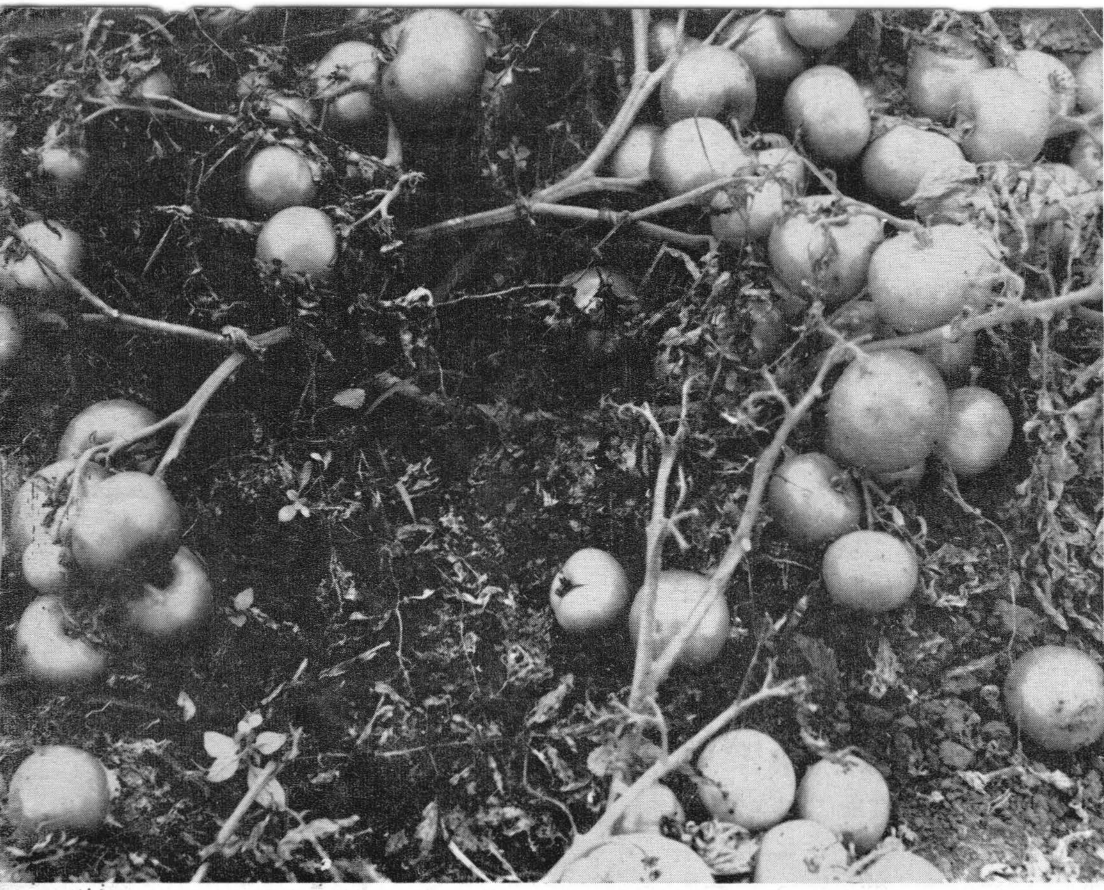

Tomato

DEFOLIATION DISEASES IN HAWAII AND EXPERIMENTS ON THEIR CONTROL

J. WALTER HENDRIX, H. MURAKISHI, AND J. A. LYLE

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DEFOLIATION DISEASES IN HAWAII AND EXPERIMENTS ON THEIR CONTROL

by

J. WALTER HENDRIX, H. MURAKISHI, AND J. A. LYLE[1]

PURPOSE OF THE BULLETIN

The purpose of this bulletin is threefold: (1) to promote a better understanding of the diseases which normally attack tomato foliage in Hawaii; (2) to promote a better understanding of the importance of these diseases in island tomato production; and (3) to report the results of control experiments made on some of the newer fungicides during the past few years.

THE TOMATO INDUSTRY IN HAWAII AND THE ROLE OF DEFOLIATION DISEASES

During the past decade the tomato crop has brought more than a half million dollars each year to the farmers of Hawaii. From 1943 through 1945, the peak years in island tomato production, its value was approximately one and a quarter million dollars (*2*).[2] This cash income is more than that provided by any other vegetable crop in the Territory.

Each year foliage diseases exact tremendous tolls from the value of the tomato crop. Depending upon the time of planting, location of field, variety used, and disease control measures employed such tolls vary from small proportions to virtually 100 percent of the total crop value. Perhaps for the islands as a whole, 20 percent of the yearly value of the crop would be a conservative estimate of the losses caused by this group of diseases.

THE MAJOR TOMATO LEAF DISEASES IN HAWAII

The diseases which most commonly cause defoliation of tomatoes in seedbeds and in the field are gray leaf spot, early blight, late blight, and *Septoria* leaf spot. A discussion of these diseases follows.

Gray leaf spot.—Gray leaf spot, frequently referred to as *Stemphylium* leaf spot, is caused by the fungus *Stemphylium solani* Weber. It is capable of causing injury from the time the seedlings emerge from the ground until the plants are mature. Although very young plants are seldom seriously affected, a few instances are known in which outside beds of plants in the

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[1]Formerly located at the University of Hawaii Agricultural Experiment Station; now at Alabama Agricultural Experiment Station.

[2]Numbers in parentheses refer to items in the Literature Cited.

four-leaf stage (plants about 3 weeks old) have been almost completely defoliated. Normally, heaviest infection occurs after the plants have been transplanted to the field and after the fruits have set. A careful examination will show that the older leaves located near the ground are usually the first to show signs of infection.

The causal fungus does not harm the fruit but confines its attack to the leaves and, to some extent, the young stems. The spots produced vary in size from less than 1/32 of an inch in diameter to approximately 1/8 inch (fig. 1). Occasionally two or more spots will fuse together to leave an even larger spot. The spots are inclined to be slightly depressed on the lower surface of the leaf but not noticeably depressed on the top surface. They have a glazed, grayish appearance when viewed from below and appear as

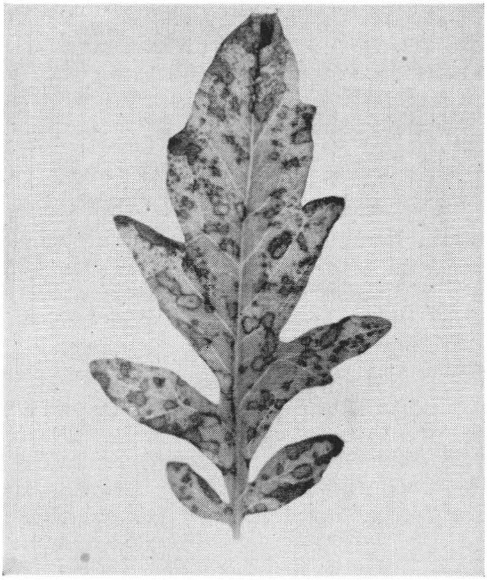

FIG. 1. Bounty tomato leaflets seriously affected by gray leaf spot. Such varieties as Bounty, Pearl Harbor, Pritchard, and Rutgers are susceptible.

grayish-brown spots from above. If the spotting is mild and well scattered, killing of the leaves may not be observed, but if the spots are numerous the affected leaves soon turn yellow and die (fig. 2). If the killing has been particularly rapid, the dead leaves may not drop immediately from the plant but may remain attached to the plant for periods up to 2 weeks.

There are now available a number of high-yielding, high-quality line selections which are resistant to gray leaf spot (*3, 4, 6*). These lines, while adapted for use at the lower elevations of the islands, are not particularly well suited for the higher areas. The varieties most commonly grown at the higher locations, such as Pritchard and Rutgers, are susceptible.

Early blight.—Early blight is caused by the fungus *Alternaria solani* (E. & M.) Jones and Grout. It differs from gray leaf spot in the type of lesions it produces and in the fact that it occurs frequently on the fruits and stems. It is primarily a disease of older plants but occasionally it is important on seedling plants where the stems and sometimes the leaves are affected.

In field plantings infection may only occasionally be noted on young, vigorously growing plants but on older plants infection is common and defoliation often occurs. The first signs of infection on the leaves are small, dark brown or black spots with irregular or diffuse margins. In the younger stages these spots sometimes may resemble those of gray leaf spot but as they enlarge the difference between them becomes apparent. Early blight lesions soon become dark brown and do not necessarily cease to enlarge. Instead, they may grow progressively larger until they are 1/2 inch or more in diameter. Upon close examination the spots appear to be made up of concentric rings; that is, one ring around the other (fig. 3). As in the case of gray leaf spot, the older lower leaves are attacked first, and badly affected leaves soon turn yellow and drop from the plant (fig. 4).

Stem lesions vary in size and shape from small circular spots of 1/8 inch in diameter to elongated spots of 3 or more inches in length. In young plants, such stem lesions may girdle the plant and kill it. If the plant is not killed, they may cause such injury that future growth is greatly retarded. Stem infection commonly occurs among plants grown in overcrowded stands or among plants grown under conditions of poor ventilation and high humidity. Young plants may develop such lesions after being transplanted to the field if the soil remains wet for long periods of time.

Resistance to the collar rot (stem lesion) phase of the disease in some lines is being observed by the Hawaii Experiment Station (*5*) but no source of resistance to *Alternaria* leaf spot has yet been found.

Late blight.—Late blight, known also as downy mildew, is caused by the fungus *Phytophthora infestans* (Mont.) DeBary. Under conditions favorable for its development, it may be found on vine and fruit at any stage of growth. It is capable of spreading with such speed that fields of tomatoes may be completely destroyed within a few days.

On the leaves, late blight lesions first appear as water-soaked or dirty green spots of 1/4 inch or less in diameter. In wet, moderately cool weather these spots enlarge rapidly, sometimes by as much as 1/2 inch each day. From the lower surfaces of the spots a downy or cottony growth appears which is characteristic of the disease and which does not appear on gray leaf spot or early blight lesions. Infected leaves do not gradually turn yellow as in the case of gray leaf spot and early blight, but instead they turn brown very quickly and die.

Infection on the fruits appears as greenish-brown spots which may involve the entire fruit if the fruit is small, or which may grow to be 2 or 3 inches in diameter if the fruit is large. Sometimes the spots are made up of concentric ridges and sometimes the infected surface is irregular with no definite pattern evident. During periods of cool, rainy weather these spots may become covered with a cottony growth similar to that found on infected leaves. At first the infected fruit tissue is firm but as secondary bacteria and fungi invade it, the tissue begins to break down and finally rots.

Stem lesions commonly follow late blight infection and this phase of the disease is sometimes quite important. Under island climatic conditions, the fungus is usually able to continue its activity in the stem even with the advent of bright, dry weather. This results in the eventual girdling of the stem so that the vine dies from the point of infection to the tip of the stem.

A degree of late blight resistance has been found in certain tomato lines in the continental United States but thus far these lines have shown little promise of resisting the disease in Hawaii (*5*).

FIG. 2. A Pearl Harbor tomato plant completely defoliated by gray leaf spot when only about half of the fruits had been harvested.

Septoria *leaf spot.*—*Septoria* leaf spot, often referred to as *Septoria* blight, is caused by the fungus *Septoria lycopersici* Speg. In periods of moderately cool weather and abundant rainfall, the disease may be of importance and may cause extensive defoliation. The disease is not found on the fruits to any great extent but is found primarily on the leaves. Occasionally some stem spotting and blossom spotting may occur but usually these phases of the disease are not serious.

Septoria leaf spot is usually found first on the lower, older leaves of plants which have already set their fruit. Leaves and leaflets which have numerous spots turn yellow, die, and drop from the plant. In the event of very severe infection, only the leaves at the tips of branches may remain and the fruits may be exposed to sun scald. In these respects, the disease is similar to gray leaf spot and early blight.

Septoria spots vary in size from 1/32 to 1/8 inch in diameter. They are roughly circular in outline and as they become older they become ashen gray in color and acquire dark margins. Tiny black dots (the spore-bearing bodies of the fungus) appear in these spots which help in distinguishing the disease from early blight and gray leaf spot (fig. 5).

Resistance to *Septoria* leaf spot is not available in any adapted commercial tomato variety in Hawaii. A degree of tolerance is present in certain lines under experimentation by the Hawaii Agricultural Experiment Station, but their final value awaits determination (*5*).

THE OCCURRENCE OF TOMATO LEAF DISEASES IN HAWAII

The development and spread of the defoliation diseases depend largely upon prevailing weather conditions. In general, periods of moderately cool weather accompanied by overcast skies, prolonged rainy periods, or heavy nightly dews are conducive to their rapid development. Such conditions normally occur during the winter months, when severe defoliation may be anticipated unless control measures are employed. Conversely, hot, dry weather, occurring during the summer in many agricultural areas of the islands, tends to retard the spread of foliar diseases.

These generalizations must not be considered as unbreakable rules because, irrespective of season, some areas are within a constant hazard zone, while in others, defoliation is uncommon at any season. At the higher elevations as in upper Olinda, Maui, and the volcano area, Hawaii, *Septoria* leaf spot, early blight, and late blight invariably prevail throughout the winter and are frequently destructive during the summer. At some lower locations, such as Kawaihae, Hawaii, the climate is such that defoliation is seldom observed even in winter. In Kona, Hawaii, the wet season usually coincides with the warmer summer weather, and heavy nightly dews characterize the winter. In such an area early and late blight in the winter and early blight and *Septoria* leaf spot in the summer jeopardize the tomato crop.

The seasonal occurrence of tomato defoliation has been recognized by a majority of island farmers and many have refrained from growing this crop during the months when heavy losses are especially likely. Production records (*2*) for the past few years show that maximum planting as well as maximum production coincides with the warmer, drier months, while in winter an insufficient quantity of tomatoes is produced.

FUNGICIDES FOR SPRAYING TOMATOES

Fungicidal protectants have been and must continue to be relied upon in combating this complex of defoliation diseases. Although excellently adapted line selections resistant to gray leaf spot are soon to be released as named varieties (*3*) and although a degree of resistance to late blight and *Septoria* leaf spot is in the process of being evaluated for the Hawaiian Islands (*5*), no single variety is known which can successfully withstand the attack of all the common diseases. Therefore, until such time as an all-resistant variety is developed, the use of fungicides would seem imperative in the successful production of tomatoes.

Until a few years ago the choice of fungicides was limited and fairly simple. Bordeaux mixture and cuprous oxide (Yellow Cuprocide) were used as a cure-all for tomato foliage troubles. Bordeaux mixture was subsequently observed to cause plant injury when used at the warmer, lower elevations and cuprous oxide became unavailable soon after the advent of war in 1941. It was only after the end of the war in 1945 that this fungicide was returned to the market. In the meantime, Spraycop gained local prominence and assumed the role previously held by Bordeaux mixture and yellow cuprous oxide.

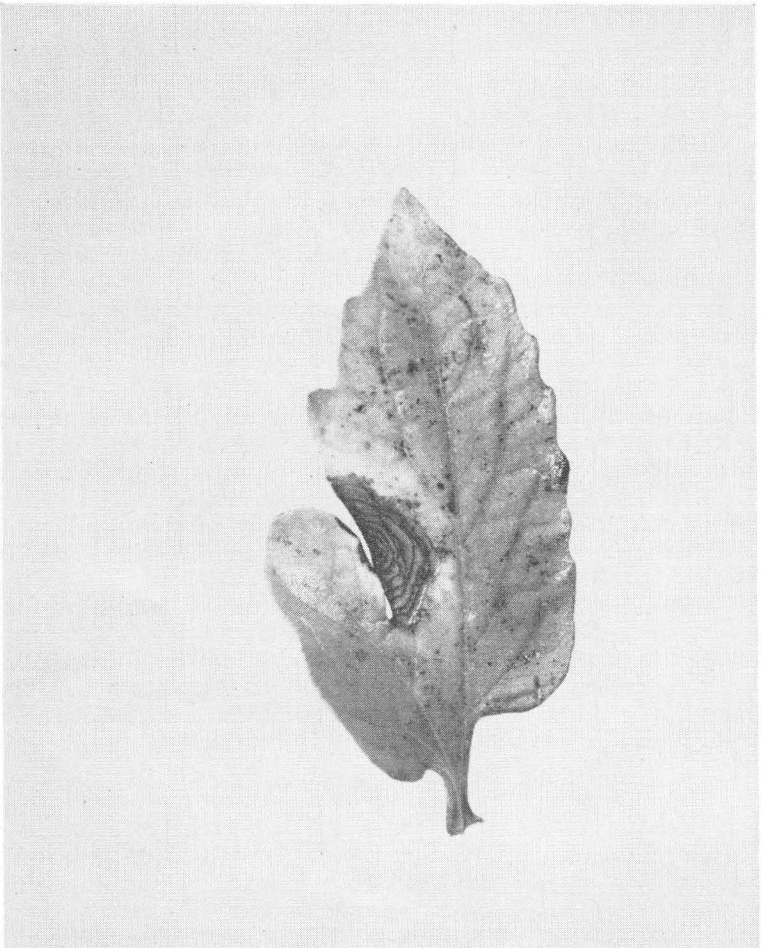

FIG. 3. A hybrid tomato leaflet showing an early blight lesion with concentric rings.

A few years ago a number of organic compounds possessing marked fungicidal properties appeared on the market (*1*) and some of them were introduced and tested in Hawaii. Among the materials included in comparative evaluation tests were members of three major groups of organic fungicides, viz., dithiocarbamic acid derivatives, quaternary ammonium derivatives, and a quinone compound, dichloronaphthoquinone. These materials were included in one or more replicated spray tests to determine their adaptability and relative value as a tomato protectant in Hawaii. Included also in the tests were such previously used materials as Bordeaux mixture, cuprous oxide (Yellow Cuprocide), and basic copper sulfate (Spraycop and tribasic copper sulfate). Following is a list of materials tested, their chemical composition, and the strengths at which they were used.

Bordeaux mixture (copper sulfate-lime)	3–3–50
Yellow Cuprocide (cuprous oxide—83 percent metallic copper)	2 lbs./100 gal.
Tribasic copper sulfate (53 percent metallic copper)	4 lbs./100 gal.
Spraycop "340" (basic copper sulfate—34 percent metallic copper)	4 lbs./100 gal.
Fermate (ferric dimethyldithiocarbamate)	2 lbs./100 gal.
Zerlate (zinc dimethyldithiocarbamate)	2 lbs./100 gal.
Parzate (zinc ethylene bisdithiocarbamate)	2 lbs./100 gal.
Dithane A-10, powder (disodium ethylene bisdithiocarbamate)	2 lbs./100 gal.
plus { zinc sulfate	1½ lbs./100 gal.
{ lime	1 lb./100 gal.
Dithane D-14, liquid (disodium ethylene bisdithiocarbamate)	2 qts./100 gal.
plus { zinc sulfate	1½ lbs./100 gal.
{ lime	1 lb./100 gal.
Phygon, wettable (dichloronaphthoquinone)	¾ lb./100 gal.
Isothan Q-15, liquid (lauryl isoquinolinium bromide)	1 pt. (20% active)/100 gal.
Check	————

METHODS OF TESTING

Two field spray tests were made at Poamoho, North Oahu, and a single test was made at Makawao, Maui. The first test was made during the winter of 1944–45, the second in the winter of 1946–47, and the third in the winter of 1948–49. The winter season was selected because it is during these cooler, wetter months that the diseases cause greatest damage. The Pearl Harbor tomato was chosen as the test variety in the first two cases because it is susceptible to all the common foliar parasites and because it is resistant to spotted wilt, a virus disease which sometimes greatly reduces the stand of tomatoes in that area. HES 3549[3] was used in the Maui test because of its adaptability to that area.

In each test the experiment was set up in a randomized block arrangement, using 12-plant spray units replicated five times. The spacing between plants in the row was 3½ feet and the inter-row distance was 7 feet. All of the fungicides were applied after the first fruit clusters were set, with a 50-gallon power sprayer adjusted to deliver 350 pounds' pressure at the pump. The sprays were applied by means of a three-outlet spray gun with shutoff valve. The spray gun was attached to a 150-foot hose which was dragged between rows to reach the various parts of the field. The tomatoes from the 10 center plants of each 12-plant spray unit were harvested, graded according to U.S. standards, and weighed. The end plants—one plant at each end of

[3]HES refers to Hawaii Agricultural Experiment Station selection numbers.

each plot—were considered as border plants and consequently were not included in the yield tally.

In the 1944–45 test, nine spray applications were made, starting when the plants were placed in the field and continuing at about 9-day intervals. In the second test, 1946–47, seven applications were made and they also were made at about 9-day intervals. In the Maui test, 1948–49, because of cooler weather and subsequent slower plant growth, 12 applications were made. In each spray the wetting agent, Triton B-1956, was added at the rate of 4 ounces per 100 gallons of solution. The rate of application per acre of the spray materials varied with the size of plants. In the first application, approximately the equivalent of 75 gallons of each spray was applied per acre; in the final applications approximately 250 gallons were required.

RESULTS

THE 1944–45 TEST

Although the test was made at the time of year when it was expected that the tomato leaf blights would develop with extreme rapidity, generally hot, dry weather prevailed until the field was within the harvest stage and appreciable defoliation did not occur until the later stages of the test. Gray leaf spot began to appear when the first fruits were in the "marble" stage and it later proved to be the predominating disease. Early blight appeared later and caused extensive late injury. *Septoria* leaf spot was present in the field but it caused minor damage. Late blight appeared with the advent of wet weather during the final days of harvest but did no appreciable harm. No comparative records of the incidence of individual diseases were made. Only records of yields of fruits were collected.

TABLE 1. Yield of tomatoes in the 1944–45 test in tons per acre.

Treatment*	Total yield in tons per acre	Yield of marketable fruits in tons per acre
Bordeaux mixture	17.04	12.38
Yellow Cuprocide	19.87	15.71
Tribasic copper sulfate	22.72	17.18
Spraycop "340"	20.04	14.80
Fermate	23.96	15.55
Zerlate	25.21	17.21
Dithane A-10	23.65	14.76
Check	17.44	11.88
Least significant difference$_{05}$**	2.07	2.12

*The following commercial materials used in this test were furnished free of charge by the manufacturers: Yellow Cuprocide and Dithane A-10 were supplied by Rohm and Haas Company, tribasic copper sulfate by the Tennessee Copper Company, Fermate and Zerlate by E. I. du Pont de Nemours and Company.

**The yield data were analyzed statistically and the least significant difference between total yield averages at 19:1 odds was obtained. This means that unless any two treatments differ in yield by as much as 2.07 tons, no legitimate claim of superiority for one over the other can be made.

The results of this experiment, summarized in table 1, show that a large difference existed between treatments in total yield of tomatoes and in yield of marketable fruits.[4] The treatment giving the highest total yield, 25.21 tons per acre, was Zerlate.[5] Zerlate was followed in descending order by Fermate (23.96 tons), Dithane A-10 (23.65 tons), tribasic copper sulfate (22.72 tons), Spraycop "340" (20.04 tons), Yellow Cuprocide (19.87 tons), and Bordeaux mixture (17.04 tons). The yield of the Bordeaux-sprayed plots was slightly lower than that of the untreated check (17.44 tons) but the yield of all of the other treatments was significantly better than that of the check. If the total yield of various treatments is considered as a measure of protection provided by the treatments, the organic materials were better than the copper fungicides and the copper fungicides were superior to no treatment.

FIG. 4. Defoliation of Pearl Harbor tomato by early blight. Many of the fruits on this plant were affected.

The highest yield of marketable tomatoes was recorded for Zerlate, followed by tribasic copper sulfate, Yellow Cuprocide, Fermate, Spraycop, Dithane A-10, and Bordeaux mixture in descending order. The yield of each of these treatments was better than that of the check and in all cases except Bor-

[4]Tomato grades U.S. No. 1 and U.S. No. 2 were considered as marketable.
[5]To aid in the interpretation of the yield data, individual plot yields were converted to tons per acre.

deaux, the difference was significant. Bordeaux mixture at a 3-3-50 strength caused noticeable injury to the young plants.

THE 1946–47 TEST

The 1946–47 test was made at the same season of the year and in a similar manner as that of 1944–45. Because of the poor showing of Bordeaux mixture in the earlier test, it was not included here. Phygon and Isothan Q-15 were introduced in this test, and Dithane D-14, a liquid, was substituted for Dithane A-10, a powder.

Gray leaf spot, early blight, and late blight appeared early in the test and when combined they caused severe defoliation in some plots. *Septoria* leaf spot was not noted at any time during the test.

In addition to securing yield records from the various treatments, the prevalence of each disease was observed and recorded. In making the disease count 10 leaves were taken from each plant in a predetermined systematic manner, and each disease lesion was diagnosed and recorded. This count was made when the earlier fruit clusters were in the mature green stage.

The average number of lesions of each disease is given in table 2.

TABLE 2.—The average number of lesions of each kind of disease found on 10 10-leaf samples for each treatment, 1946–47 test.

Treatment*	Number of lesions			
	Gray leaf spot	Early blight	Late blight	Total all diseases
Yellow Cuprocide	77	58	3	138
Tribasic copper sulfate	64	46	3	113
Fermate	24	26	4	54
Zerlate	14	11	1	26
Dithane D-14 (with lime and zinc sulfate)	47	52	1	100
Phygon	161	174	11	346
Isothan Q-15	144	140	8	292
Check	486	583	59	1,128
Least significant difference$_{.05}$	63	42	9	55

*The following commercial materials used in this test were furnished free of charge by the manufacturers: Phygon by the United States Rubber Company and Isothan Q-15 by the Onyx Chemical Corporation.

The results of this tabulation show that all treatments significantly reduced the incidence of each disease below that of the unsprayed check. Zerlate, as indicated by the small number of leaf spots, provided greatest protection against gray leaf spot and early blight and equaled Dithane D-14 in preventing late blight.[6] From the standpoint of controlling all of the diseases, Zerlate was the best. Fermate also provided excellent protection against all the diseases and was not significantly inferior to Zerlate. Dithane

[6]In most tests where the ability of tribasic copper sulfate and Yellow Cuprocide to control late blight has been compared with that of Zerlate and Fermate, the coppers have proved more satisfactory.

D-14, tribasic copper sulfate, and Yellow Cuprocide provided roughly equal protection to the plants but were not as effective as Zerlate and Fermate. Phygon and Isothan Q-15 were the least effective of the fungicides.

TABLE 3.—Total yield and yield of marketable tomatoes in tons per acre, 1946–47 test.

Treatment	Total yield	Yield of marketable fruits
Yellow Cuprocide	10.46	7.86
Tribasic copper sulfate	11.07	8.68
Fermate	10.86	8.03
Zerlate	13.10	10.39
Dithane D-14	10.16	8.38
Phygon	4.32	3.36
Isothan Q-15	6.03	4.81
Check	7.37	4.96
Least significant difference$_{.05}$	2.38	1.79

The data (table 3) indicate that the yield of the unsprayed check was significantly exceeded by Zerlate, Fermate, Yellow Cuprocide, tribasic copper sulfate, and Dithane D-14-zinc-lime. The plots sprayed with Zerlate yielded significantly more tomatoes than any of the other plots except Fermate and tribasic copper sulfate. The plots sprayed with Fermate, Yellow Cuprocide, tribasic copper sulfate, and Dithane D-14 gave roughly the same yield, there being no significant difference between them.

The plants sprayed with Phygon and Isothan Q-15 yielded a lower

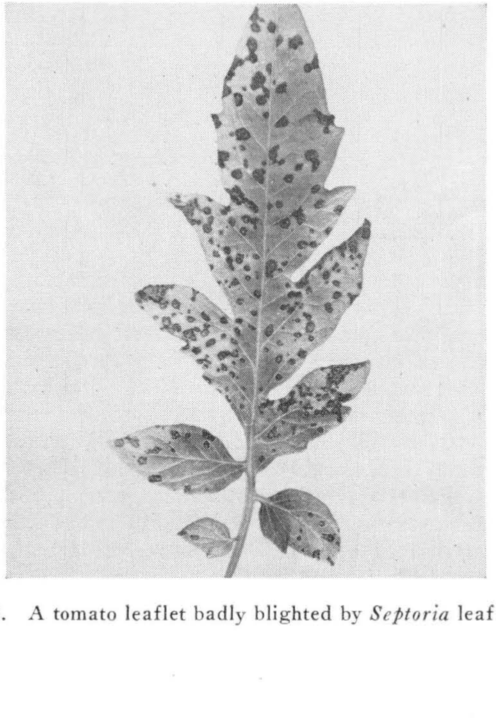

FIG. 5. A tomato leaflet badly blighted by *Septoria* leaf spot.

tonnage of tomatoes than the unsprayed plants. Phygon, at 3/4 pound per 100 gallons of water, caused severe burning of the foliage and produced some russeting of the fruits.

From the standpoint of the yield of marketable fruits the Zerlate, Fermate, Dithane D-14, tribasic copper sulfate, and Yellow Cuprocide treatments were better than the untreated check. Zerlate was the best of them all, and with the exception of tribasic, its superiority was significant.

THE 1948–49 TEST

Makawao, Maui (elevation 2,400), was selected as the site of the third test because its climate is relatively cooler than that in the lower tomato areas of Oahu, and because it is more closely representative of the commercial vegetable areas of Maui. In this location late blight, *Septoria* leaf spot, and early blight usually cause greater damage than they do in most of the Oahu centers of production.

At the beginning of fruit harvest a leaf spot determination revealed the presence of all the principal foliage diseases except gray leaf spot—HES 3549 is resistant to this disease. Midway in the harvest process a second count of leaf diseases was made, and the number of leaf lesions on each of 10 systematically selected leaves from each plant was ascertained. The total number of lesions found on 500 leaves (10 leaves × 10 plants × 5 replications) of each treatment is given in table 4.

TABLE 4.—Total number of disease lesions per 500-leaf unit, 1948–49 test.

Treatment	Number of lesions		
	Early blight	*Septoria*	Total lesions
Zerlate	197	4	201
Parzate	524	70	594
Dithane D-14	382	5	387
Tribasic copper sulfate	516	7	523
Yellow Cuprocide	924	9	933
Check (unsprayed)	3,592	29,238	32,830
Least significant difference$_{.05}$ excluding check			24

The reduction in numbers of disease lesions resulting from the use of fungicidal sprays was highly significant. Early blight was present in considerable proportions in all plots but even the least effective material, Yellow Cuprocide, reduced the number of lesions far below the unsprayed check. The most effective material, Zerlate, reduced the incidence of early blight infection from 3,592 lesions in the check to 197 lesions for the same number of leaves. Leaf spotting by *Septoria lycopersici* was almost completely eliminated by Zerlate, Dithane D-14, tribasic, and Yellow Cuprocide. Although a total of 70 *Septoria* lesions was found among plants sprayed with Parzate, this number seems inconsequential in comparison to the 29,238 lesions found on unsprayed leaves. Late blight, present in earlier stages of plant growth, disappeared during the later phases of the experiment; accordingly an evaluation of the fungicides for its control was not made.

The yield of marketable tomatoes (table 5) was improved by the application of tribasic copper sulfate (which yielded 14.90 tons per acre), Yellow Cuprocide (14.40 tons), Zerlate (13.66 tons), and Parzate (12.68 tons). Dithane D-14, with a yield of 11.37 tons per acre, was slightly poorer than the untreated check, 11.40 tons per acre. The improvement afforded by tribasic copper sulfate and Yellow Cuprocide is statistically significant but the increased yields of Zerlate and Parzate fall short of the 2.38 tons required for significance.

TABLE 5.—Effects of five fungicidal sprays on the yield of marketable tomatoes, 1948–49 test. (Tons per acre.)

Treatment	Total yield	Yield of marketable fruits
Zerlate	20.63	13.66
Parzate	20.23	12.68
Dithane D-14	17.41	11.37
Tribasic copper sulfate	21.28	14.90
Yellow Cuprocide	19.80	14.40
Check	17.90	11.40
Least significant difference$_{.05}$		2.38

GROSS VALUE GAINED BY SPRAYING

The increases in yield of marketable tomatoes and the consequent gross increases in monetary value brought about by applying the various fungicides are listed in table 6 for the Poamoho (1944–45 and 1946–47) and Maui (1948–49) tests. In computing the increases in value, 16.5 cents was used as the farmer's price per pound of winter tomatoes from 1945 to 1947 inclusive, and 11.8 cents per pound for 1948–49 winter tomatoes.[7] If the costs of material, labor, and equipment are not considered, the gross increase in value varied in the 1944–45 test from $950 per acre for Dithane A-10 to $1,759 for Zerlate. In the 1946–47 test, the extent of increase ranged from $957 for Yellow Cuprocide to $1,792 for Zerlate. In the 1948–49 test the increase varied from minus $9 in the case of Dithane D-14-zinc-lime to plus $826 for tribasic copper sulfate.

Since the yields from the plots sprayed with Bordeaux mixture, Phygon, and Isothan Q-15 were no better than the untreated plots, these materials were excluded from table 6.

THE COST OF SPRAYING

Earlier in the report it was pointed out that nine applications of each spray mixture were made in the first test, seven applications in the second, and 12 in the final test. It was also pointed out that the rate of application varied between 75 and 250 gallons per acre, depending on the size of plants, and that the wetting agent Triton B-1956 was included with each fungicide

[7]These figures were calculated from wholesale tomato prices published by the Department of Agricultural Economics of the University of Hawaii College of Agriculture. They represent average farmers' prices for tomatoes during December, January, February, March, April, and May of the years when the tests were made.

at the rate of 4 ounces for each 100 gallons of spray mixture. According to records kept the equivalent of approximately 2,000 gallons of each spray mixture was used per acre in each of the three tests.

TABLE 6.—Increases in yield and value of marketable fruits among sprayed plots as compared with unsprayed plots; 1944–45, 1946–47, and 1948–49 tests.

Treatment	1944–45 test		1946–47 test		1948–49 test	
	Increase in yield	Increase in value	Increase in yield	Increase in value	Increase in yield	Increase in value
	tons	*dollars*	*tons*	*dollars*	*tons*	*dollars*
Fermate	3.67	1,211	3.07	1,013	......	......
Parzate	......	......	......	......	1.28	302
Zerlate	5.33	1,759	5.43	1,792	2.26	533
Dithane D-14	2.88	950	3.42	1,129	–0.04	– 9
Yellow Cuprocide	3.83	1,264	2.90	957	2.99	706
Tribasic copper sulfate	5.30	1,749	3.72	1,228	3.50	826
Spraycop "340"	2.92	964	......	......	......	......
Check	......	......	......	......	......	......

Cost of fungicides and wetting agent.—To make 2,000 gallons of each of the spray mixtures at the strengths listed on page 9, 40 pounds of Yellow Cuprocide were required, 80 pounds of Spraycop "340," 80 pounds of tribasic copper sulfate, 40 pounds of Fermate, 40 pounds of Zerlate, and 7.5 gallons of Dithane D-14. The equivalent of 80 ounces of Triton B-1956 was used with each of these materials. In table 7 are listed the cost per pound of each fungicide, the cost of the wetting agent, and the total cost of making 2,000 gallons of each spray mixture.

TABLE 7.—The cost of fungicides used and the cost of making sufficient gallonage of mixture (2,000 gallons) to protect tomatoes—expressed on per acre basis.

Fungicide	Cost of fungicide[1]	Cost of fungicide required in making 2,000 gallons of spray mixture	Cost of wetting agent used in 2,000 gals. of spray	Total cost of materials needed for 2,000 gallons of spray
Fermate	$1.10 per lb.[2]	$44.00	$4.50	$48.50
Parzate	1.61 per lb.[2]	64.40	4.50	68.90
Zerlate	1.10 per lb.[2]	44.00	4.50	48.50
Dithane D-14	3.80 per gal.[3]	38.00	4.50	42.50
Yellow Cuprocide	0.57 per lb.[4]	22.80	4.50	27.30
Tribasic copper sulfate	0.45 per lb.[5]	36.00	4.50	40.50
Spraycop "340"	0.40 per lb.[6]	32.00	4.50	36.50

[1]These costs represent September, 1949, Honolulu retail quotations.
[2]Approximate cost per pound in 25-pound cartons.
[3]Approximate cost per gallon in 30-gallon drums.
[4]Approximate cost per pound in 100-pound cartons.
[5]This material has thus far not been offered for sale locally; therefore, this figure is the estimated cost per pound.
[6]Approximate cost per pound in 48-pound cartons.

The cost of materials required for protecting 1 acre for the full life of the crop varied, depending on the fungicide, between $27.30 and $68.90. The least expensive material used was Yellow Cuprocide and the most expensive was Parzate. The cost of the other fungicides fell between these limits.

Cost of labor.—The number of man-hours required for spraying an acre of tomatoes depends upon the size of plants, inter-row spacing of plants, topography of the field, shape of rows, type of equipment used, manner of applying sprays, and possibly other factors. In the tests reported here and in subsequent similar operations where the topography of the land prevented entry into the field with motor-drawn equipment and where spray hoses were pulled to various parts of the field by hand, an average of about 13 man-hours was required to make a single application on 1 acre. Under present wage scales in Hawaii, farm labor costs usually amount to about 90 cents per man-hour. This means, therefore, that using the spray system as outlined on page 9, the cost of making a single application on a single acre would have been approximately $11.70, exclusive of cost of materials.

NET VALUE GAINED FROM SPRAYING

The net values gained from applying the various fungicides, computed by subtracting the cost of materials and labor from the gross value gained, in the 1944–45, 1946–47, and 1948–49 tests are given in tables 8, 9, and 10, respectively. The figures given in these tables illustrate the importance of spraying tomatoes in areas where leaf diseases are likely to affect the yield of marketable produce. In the first test, for example, the use of Zerlate and tribasic copper sulfate increased the value of the crop by approximately $1,600 per acre, while Fermate and Yellow Cuprocide each provided more than $1,000 increases. Even the less effective protectors, Dithane-zinc-lime and Spraycop, gave increases of about $800 per acre.

In the second test the increases in crop value were almost as great as in the earlier test. Zerlate gave a net increase of a little more than $1,600 per acre and tribasic copper sulfate and Dithane-zinc-lime increased the crop value by roughly $1,000. The lowest increases provided by Fermate and Yellow Cuprocide were above $800.

TABLE 8.—A comparison of costs of materials and labor with value gained following use of six fungicidal materials, 1944–45 test.

Fungicide	Gross value gained	Cost of materials	Cost of labor (9 applications)	Total costs	Net value gained
Fermate . .	$1,211	$48.50	$105.30	$153.80	$1,057.20
Zerlate . .	1,759	48.50	105.30	153.80	1,605.20
Dithane-zinc-lime	950	42.50	105.30	147.80	802.20
Yellow Cuprocide	1,264	27.30	105.30	132.60	1,131.40
Tribasic copper sulfate . .	1,749	40.50	105.30	145.80	1,603.20
Spraycop "340" .	964	36.50	105.30	141.80	822.20

TABLE 9.—A comparison of costs of materials and labor with value gained following use of five fungicidal materials, 1946–47 test.

Fungicide	Gross value gained	Cost of materials	Cost of labor (7 applications)	Total costs	Net value gained
Fermate . .	$1,013	$48.50	$81.90	$130.40	$ 882.60
Zerlate . .	1,792	48.50	81.90	130.40	1,661.60
Dithane D-14-zinc-lime	1,129	42.50	81.90	124.40	1,004.60
Yellow Cuprocide	957	27.30	81.90	109.20	847.80
Tribasic copper sulfate . .	1,228	40.50	81.90	122.40	1,105.60

TABLE 10.—A comparison of costs of materials and labor with value gained following use of five fungicidal materials, 1948–49 test.

Fungicide	Gross value gained	Cost of materials	Cost of labor (12 applications)	Total costs	Net value gained
Parzate . . .	$302	$68.90	$140.40	$209.30	$ 92.70
Zerlate . . .	533	48.50	140.40	188.90	344.10
Dithane D-14-zinc-lime	– 9	42.50	140.40	182.90	–191.90
Yellow Cuprocide	706	27.30	140.40	167.70	538.30
Tribasic copper sulfate . .	826	40.50	140.40	180.90	645.10

In the Maui test, 1948–49, the net increase in value was somewhat lower than that of former tests but nonetheless demonstrates the value of providing protection from defoliation. The greatest net increase in value was provided by tribasic copper sulfate ($645), followed in descending order by Yellow Cuprocide ($538), Zerlate ($344), and Parzate ($93). Dithane D-14-zinc-lime gave no increase over the unsprayed check in this test.

SUMMARY

Losses due to foliage diseases of tomatoes amount to an estimated 20 percent of the annual value of the island tomato crop. The principal diseases responsible are gray leaf spot, early blight, late blight, and *Septoria* leaf spot. A description of each disease is given. These diseases are particularly harmful during the winter months when, because of the generally higher prices paid by the local market, many growers would prefer to make major plantings. However, because of excessive defoliation, many farmers are forced to produce this crop only during the summer months.

The results of three tests show that plots sprayed from 7 to 12 times with certain of the newer organic fungicides and with some of the copper fungicides gave significant increases in yield of marketable fruits and significant decreases in the incidence of the leaf diseases over untreated plots.

Zerlate, used at 2 pounds per 100 gallons of water, gave a very high degree of control of gray leaf spot, early blight, and *Septoria* leaf spot when-

ever these diseases prevailed. Fermate, tribasic copper sulfate, Parzate, and Yellow Cuprocide likewise afforded excellent protection. Dithane D-14-zinc-lime increased the yield of marketable fruits in the two Poamoho tests, but failed to increase the yield at Makawao, Maui.

The highest yields of marketable fruits in the 1944–45 test were obtained from plots sprayed with Zerlate, tribasic copper sulfate, Yellow Cuprocide, Fermate, Spraycop, and Dithane-zinc-lime, in the order listed. In the second test, 1946–47, the highest yields were obtained with the use of Zerlate, tribasic copper sulfate, Dithane-zinc-lime, Fermate, and Yellow Cuprocide, in the order listed. In the third test, the use of tribasic copper sulfate provided the greatest yield, followed in descending order by Yellow Cuprocide, Zerlate, and Parzate.

The net value of the increased yield was over $1,600 per acre for Zerlate and tribasic copper sulfate in the 1944–45 test, $1,000 for Fermate and Yellow Cuprocide, and $800 for Dithane-zinc-lime and Spraycop "340." Similar values were obtained in the second test. The net value of Zerlate-sprayed plots was more than $1,600 greater than the unsprayed check. In this test Dithane D-14-zinc-lime and tribasic copper sulfate increased the value of the crop by $1,000 and Fermate and Yellow Cuprocide by $800. In the Maui test net gains of $600, $500, and $300 were obtained from tribasic copper sulfate, Yellow Cuprocide, and Zerlate, respectively.

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